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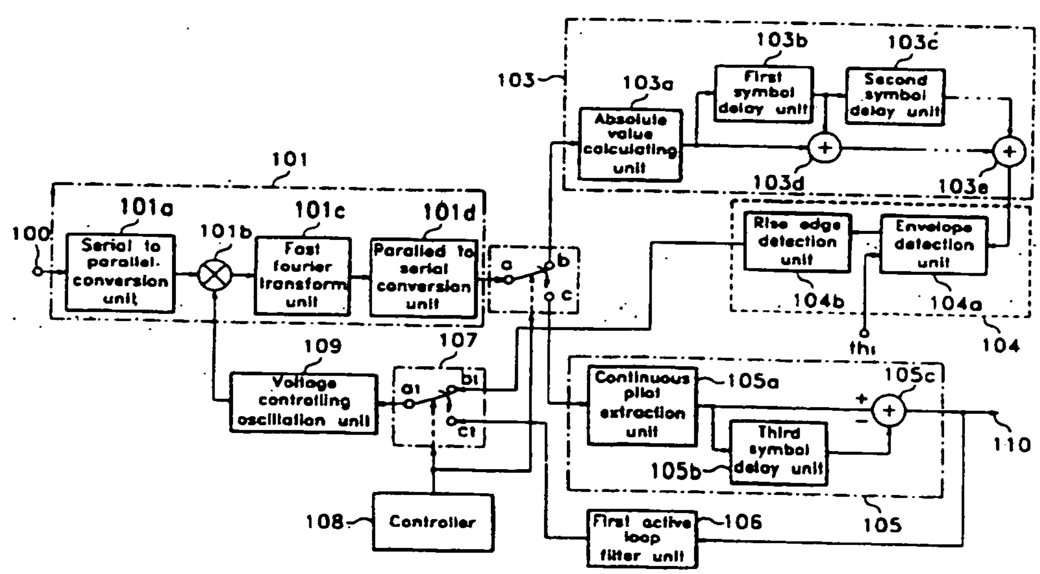
(54) Abstract Title
Synchronizing OFDM receivers

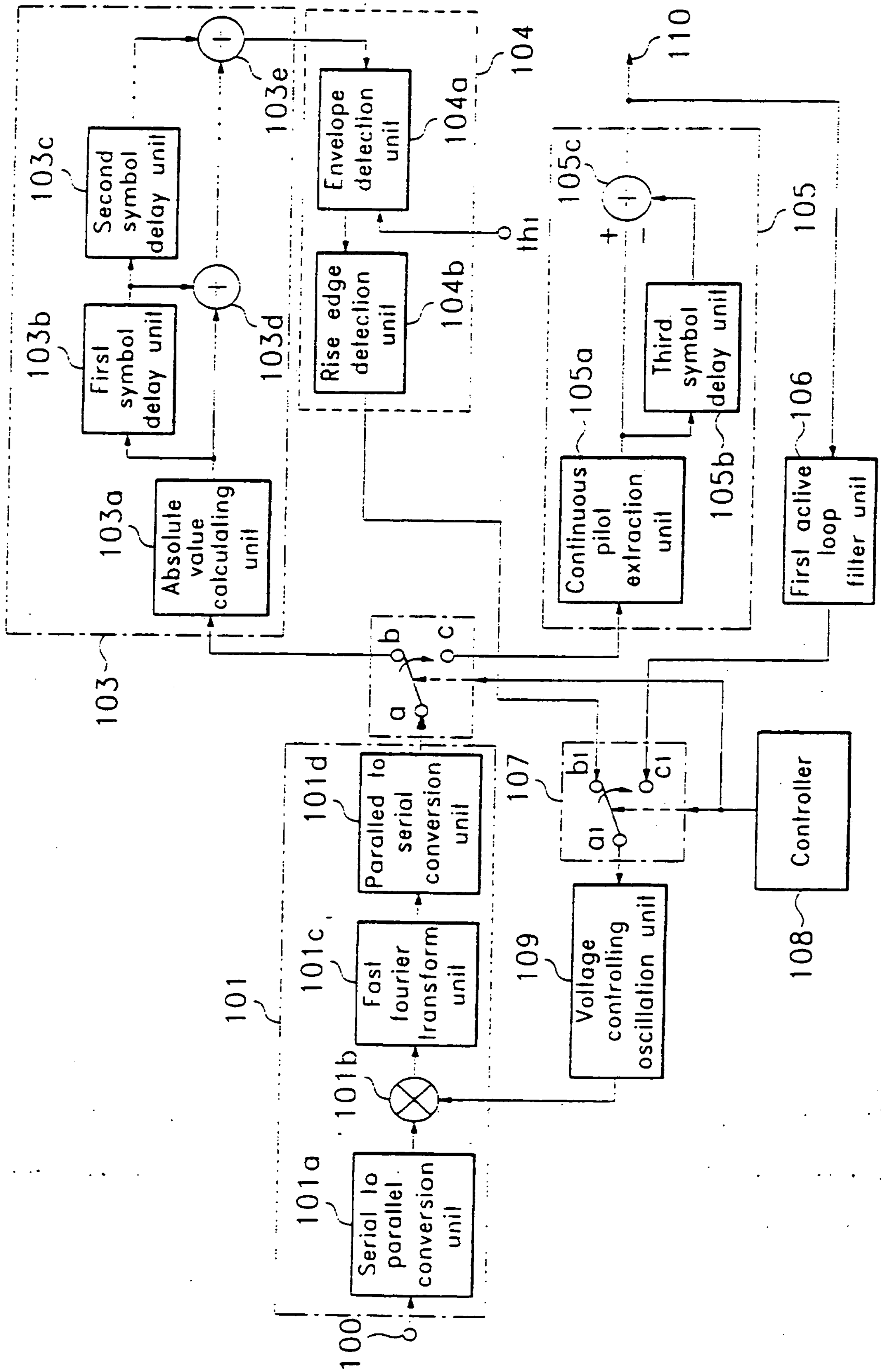
(57) The receiver of an OFDM transmission system is synchronized to compensate for carrier frequency offset by switching between: a first mode in which a local oscillator (109) in the receiver is coarsely adjusted by; calculating (103a) the signal strength of each received symbol, accumulating (103d...103e) the signal strength of the received and appropriately delayed (103b, 103c...) signal strengths of earlier symbols, determining the timing (104b) at which the accumulated signal strength reaches a predetermined threshold value (th1) and coarsely adjusting the phase of the oscillator in accordance with that timing and: a second mode in which the local oscillator is finely corrected by; extracting (105a) a pilot signal from the received signals, calculating (105c) the phase difference between the extracted pilot (or carrier) and a previously extracted pilot (or carrier) signal delayed (105b) by one symbol duration and finely adjusting the phase of the oscillator in accordance with that phase difference.

FIG. 1



GB 2 324 447 A

FIG. 1



100
101
101a
Serial to parallel conversion unit
101b
101c
Fast fourier transform unit
101d
Paralled to serial conversion unit
a
b
c
103
103a
Absolute value calculating unit
103b
First symbol delay unit
103c
Second symbol delay unit
103d
103e
104
104a
Envelope detection unit
104b
Rise edge detection unit
th1
105
105a
Continuous pilot extraction unit
105b
Third symbol delay unit
105c
+
−
106
First active loop filter unit
107
a1
b1
c1
108
Controller
109
Voltage controlling oscillation unit
110

The Patent Office

28

Application No: GB 9803514.0
Claims searched: 1 to 24

Examiner: Ken Long
Date of search: 12 August 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4P (PAL & PAR)
H4M (MFA)

Int Cl (Ed.6): H04L 27/26

Other: ONLINE : WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2313527 A	MITSUBISHI (page 3 lines 10-13, page 3 line 17 to page 4 line 11, page 6 lines 22-24 and page 7 lines 3-5)	1 & 10
X	GB 2313270 A	MITSUBISHI (page 1 lines 6-9 and page 29 lines 13-22)	1 & 10
X	GB 2313022 A	MITSUBISHI (page 1 lines 6-10 and 19, page 3 lines 4-16 and page 14 lines 19-22)	1 & 10

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

directly by the present output of said offset detecting means and an integer gain for controlling input signal of the voltage-controlled oscillating means by averaging the previous outputs of said offset detecting means.

21. The apparatus of any of claims 11 to 20, further comprising a controller for controlling said first and second switch means according to the coarse mode and the fine mode.

22. The apparatus of Claim 21, wherein said controller decides said fine mode according to the accumulated value of the symbol of said symbol accumulating means and controls said first and second mode switch means.

23. A method for synchronizing a carrier frequency of an OFDM transmission system, the method being substantially as herein described with reference to Figure 1.

24. Apparatus for synchronizing the carrier frequency of an OFDM transmission system, the apparatus being substantially as herein described with reference to Figure 1.

symbol delay means for delaying and outputting said extracted continuous pilot signal by one symbol period; and

subtracting means for obtaining the phase difference between said continuous pilot signal which is delayed during one symbol period and a present continuous pilot signal and then supplying to said loop filter means.

16. The apparatus of Claim 13, or claim 14 or 15 as dependent thereon, wherein said absolute value calculating means obtains the signal strength of said carrier by squaring an absolute value.

17. The apparatus of Claim 13 or 16, or of claims 14 or 15 as dependent upon claim 13, wherein at least two said symbol delay means and adding means are provided and accumulates the signal strength of the carrier during at least two symbols.

18. The apparatus of Claim 14, or any of claims 15 to 17 as dependent upon claim 14, wherein said threshold value is obtained by averaging the signal strengths of the carrier and compared with the value which is accumulated during a predetermined symbol.

19. The apparatus of Claim 14 or 18, or any of claims 15 to 17 as dependent upon claim 14, wherein said rise edge detection means performs counting until the envelop value detected by said envelop detection means becomes larger than said threshold value and then supplies said counted value said voltage-controlled oscillating means.

20. The apparatus of any of claims 11 to 19, wherein said loop filter means comprises first-order active loop filter having both a proportional gain for controlling the input signal of said voltage-controlled oscillating means

absolute value calculating means for calculating the signal strength of said data of carrier which is obtained by said first mode switch means;

symbol delay means for delaying the symbol successively as one symbol duration by considering said signal strength calculated by said absolute value calculating means; and

adding means for accumulating said strength value of the delayed signal by said symbol delay means and said strength value of the obtained signal by said absolute value calculating means and then outputting the accumulated value.

14. The apparatus of Claim 11, 12 or 13, wherein said hold value detection means comprises:

envelope detecting means for detecting an envelope by comparing said accumulated value of the signal strength obtained by said adding means with a predetermined threshold value; and

rise edge detection means for controlling said voltage-controlled oscillating means through said second mode switch means by calculating the detected envelope value by said envelope detecting means.

15. The apparatus of Claim 11, 12, 13 or 14, wherein said offset detection means comprises:

continuous pilot extracting means for extracting a continuous pilot signal from the serial data of carrier which is obtained by said first mode switch means;

second mode switch means for selecting and outputting one value out of the phase difference value which is filtered and then obtained by the loop filter means and the hold value obtained by the hold value detecting means; and

voltage-controlled oscillating means which is locked to the hold value or phase difference value which is selected by the second mode switch means for correcting the integer part and the prime part of the carrier frequency offset of the data demodulation means.

11. The apparatus of claim 10, further comprising control means for switching and controlling the first and second switch means with a predetermined time difference.

12. The apparatus of Claim 11, wherein said data demodulation means comprises:

serial to parallel conversion means for converting said inputted data of carrier into parallel data;

mixing means for mixing said converted parallel data and said oscillated voltage which is feedback by said voltage-controlled oscillating means;

fast Fourier transform means for extracting sample data by converting said mixed data of carrier in orthogonality by said mixing means; and

parallel to serial conversion means for converting said sample data of carrier into serial data and outputting said data.

13. The apparatus of Claim 11 or 12, wherein said symbol accumulating means comprises:

predetermined Hz by controlling the gain proportionally with the calculated value of the phase difference.

10. An apparatus for a synchronizing carrier frequency of the OFDM transmission system, comprising:

data demodulation means for sampling a received signal by an oscillating feedback voltage from the obtained data of carrier by input terminal;

first mode switch means for switching the demodulated carrier by said data demodulator means into a coarse mode or a fine mode for correcting an integer part or a prime part of a carrier frequency offset;

symbol accumulating means for accumulating the calculated strength value of the frequency offset from the obtained data of carrier which is inputted by said first mode switch means and the strength value of the accumulated carrier frequency offset which is delayed by one symbol duration;

hold value detecting means for detecting a hold value by calculating the strength value of the accumulated carrier frequency offset until the value arrives at a threshold value;

offset detection means detecting the frequency offset from the demodulated carrier obtained by the first mode switch means and then obtaining the phase difference between the carrier frequency offset of the present symbol and that of the previous symbol;

loop filter means for controlling a gain of the obtained phase difference by the offset detecting means;

2. The method of Claim 1, wherein the signal strength of said carrier frequency is obtained by the square of an absolute value of the signal amplitude.

3. The method of Claim 1 or 2, wherein the correction of the integer part of said carrier frequency offset is performed within a predetermined frequency bandwidth between each carrier.

4. The method of Claim 2, wherein, after averaging said calculated signal strength of the carrier, the averaged value is set as an established value which is the comparative value of the signal strength of the carrier.

5. The method of Claim 3, wherein the correction of the integer part of said carrier frequency offset is performed by accumulating the calculated signal strength of the present carrier and the signal strength of a previous carrier during at least two symbol periods.

6. The method of Claim 3, wherein the integer part of said carrier frequency offset is corrected within a half frequency bandwidth of one subchannel.

7. The method of any of the preceding Claims, wherein said phase difference is obtained by dividing the value which is obtained by averaging the phase differences of pilots within one symbol by a predetermined value.

8. The method of Claim 7, wherein the phase difference between the adjacent symbols is obtained by dividing said average value of the phase differences of pilots within one symbol by $2\pi\_\ (1+\Delta)$.

9. The method of Claim 7, wherein the prime part of said carrier frequency offset is corrected within a

CLAIMS

1. A method for synchronizing a carrier frequency of the OFDM transmission system comprising, the steps of:

determining which mode out of a coarse mode for correcting an integer part of a carrier frequency offset and a fine mode for correcting a prime part is selected;

calculating the strength of carrier which is received in each subchannel in the case of selecting the coarse mode;

accumulating the calculated strength of the carrier and the strength of a previous carrier which is delayed by one symbol duration for a predetermined period;

calculating the accumulated value of the strength of the carrier until the value arrives at a predetermined threshold value and correcting the integer part of the received carrier frequency offset using the calculated value;

extracting a pilot signal by receiving the carrier which is transmitted from a transmitter in the case of selecting the fine mode;

calculating a phase difference between the extracted pilot signal and a previous extracted pilot signal which is delayed by one symbol duration; and

correcting the prime part of the received carrier frequency offset within a predetermined frequency by controlling a gain of the calculated phase difference.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

oscillating unit 109 through the second mode switch unit 107. At this time, the gain of the voltage-controlled oscillating unit 109 is one (1).

The voltage-controlled oscillating unit 109 can reduce the prime part of the carrier frequency offset which is outputted from the mixing unit 101b within a several Hz by the gain of the first-order active loop filter unit 106.

Here, the natural frequency ωn should be decided as that the remaining carrier frequency offset is small and that it is possible to track the carrier in fast speed.

As described above, by moving both the coarse mode for compensating the integer part of the carrier frequency offset and the fine mode for compensating the prime part with a predetermined time difference, the synchronization of the carrier frequency in the OFDM transmission apparatus can be achieved.

While there have been illustrated and described what are considered to be preferred embodiments of the present invention, it will be understood by those skilled in the art that various changes and modifications may be made, and equivalents may be substituted for elements thereof without departing from the true scope of the present invention. In addition, many modifications may be made to adapt a particular situation to the teaching of the present invention without departing from the central scope thereof. Therefore, it is intended that the present invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out the present invention, but that the present invention includes all embodiments falling within the scope of the appended claims.

The subtracting unit 105c calculates the phase difference between the present pilot signal extracted by the continuous pilot extracting unit 105a and the pilot signal which is transmitted and extracted in the same subchannel as the previous pilot signal which is delayed by the third symbol delay unit 105b.

In other words, by averaging the phase differences of the pilots within one symbol through the continuous pilot extracting unit 105a, the third symbol delay unit 105b and the subtracting unit 105c, a presumed value regarding the carrier frequency offset can be set. The phase difference of the pilots which is transmitted in the same subchannel between the adjacent two symbols is proportional to the carrier frequency offset. By dividing this averaged value by 2π_ $(1+\Delta)$, the phase difference between the symbols can be obtained.

The phase difference obtained by the subtracter 105c is outputted through an output terminal 110 and filtered through the first-order active loop filter unit 106, thereby supplied to the second mode switch unit 107.

The first-order active loop filter unit 106 uses both a proportional gain Kp for input signal of the voltage-controlled oscillating unit 109 directly by the present output of the offset detecting unit 105 and an integer gain Ki for input signal of the voltage-controlled oscillating unit 109 by averaging the previous outputs of the offset detecting unit 105.

Here, the gains can be expressed as a natural frequency ωn, the proportional gain Kp becomes $\omega n\ (1+\omega n)$, and the integer gain Ki becomes $4\ \omega n^2$.

The signal which passes the first-order active loop filter unit 106 is inputted to the voltage-controlled

subchannel and N is the number of points which are used in the fast Fourier transform unit 101c.

In units for the fine mode, there are the offset detecting unit 105, the first-order active loop filter unit 106 and the voltage-controlled oscillating unit 109.

The offset detecting unit 105 performs the fine mode using the fast Fourier transform unit 101c, the parallel to serial conversion unit 101d, the continuous pilot extracting unit 105a, the third symbol delay unit 105b and the subtracting unit 105c.

The operation of the fine mode for correcting the prime part is illustrated. First, when the operation of the coarse mode is completed, the controller 108 converts the movable terminals a and a1 of the first and second mode switch units 102 and 107 such as the analog switch to fixed branches c and c1.

Accordingly, the fast Fourier transform unit 101b performs the fast Fourier transform of the sampled sequence by N number of points, and then supplies it to the continuous pilot extracting unit 105a of the offset detecting unit 105 through the parallel to serial conversion unit 101d, the movable terminal a and fixed branch c of the first switch unit 102.

The continuous pilot extracting unit 105a of the offset detecting unit 105 extracts the pilot components continuously among the data of carrier of N number of points which are inputted through the fast Fourier transform unit 101c, and then supplies it to the subtracting unit 105c through the third symbol delay unit 105b.

detecting unit 104a becomes larger than the threshold value th1. When the counting is completed at the rise edge point, the counted value is maintained and supplied to a fixed branch b1 of the second mode switch unit 107 such as the analog switch.

The second mode switch unit 107 is controlled together with the first mode switch unit 102 and is connected to the fixed branch b1 by the controller 108.

As a result, the hold value which is detected by the rise edge detecting unit 104b is supplied to the voltage-controlled oscillating unit 109 through the second mode switch unit 107.

The voltage-controlled oscillating unit 109 generates the oscillating voltage corresponding to the hold value which is inputted by the second mode switch unit 107 and is supplied it to the mixing unit 101b of the data demodulation unit 101. Here, the integer part of the carrier frequency offset is corrected within a half frequency bandwidth of one channel.

A timing control signal which is used in the fine mode is decided according to how many symbol durations the data of carrier is accumulated by the symbol accumulating unit 103.

Moreover, in the fine mode, the carrier frequency offset is corrected within a several Hz by using the phase difference between the continuous pilot of the symbols with the carrier frequency offset.

In other words, the carrier frequency offset(_) brings about the phase shift as much as 2π_ $(1+\Delta/N)$ to the receiving signal, where Δ is the frequency bandwidth of a

The signal strength which is obtained by the absolute value calculating unit 103a is delayed in the first and second symbol delay units 103b and 103c each by one symbol unit. The signal strength which is delayed by one symbol by the first symbol delay unit 103b and the strength value of the present signal which is inputted by the absolute value calculating unit 103a are accumulated through the first adding unit 103d. The strength value of the accumulated signal is accumulated to the signal strength which is delayed by the second symbol delay unit 103c through the second adding unit 103e, and then it is supplied to the hold value detecting unit 104.

As there is a guard band whose signal power is zero (0) in the data of carrier which is switched by the first mode switch unit 102 to take a guard margin against the mutual interference by adjacent subchannels, the data of carrier regarding carrier indexes for several symbols are accumulated and then they are supplied to the hold value detecting unit 104.

The hold value detecting unit 104 calculates the strength of the carrier accumulated by the symbol accumulating unit 103 until it reaches the threshold value th1, and checks how much the signal of the guard band is shifted. After that, the hold value detecting unit 104 corrects the integer part of the carrier frequency offset within a half band of one channel. In other words, the envelope detecting unit 104a of the hold value detecting unit 104 detects the envelope and compare the signal strength of the carrier accumulated by the symbol accumulating unit 103 with the threshold value th1. Here, the envelope is obtained by designating the threshold value th1 as the half of the signal power.

Moreover, the rise edge detecting unit 104b performs counting until the value obtained by the envelope

And then the fast Fourier transform unit 101c of the data demodulation unit 101 converts the inputted data of carrier through the mixing unit 101b orthogonally at a high speed and then outputs the Fourier-transformed data.

At this time, in the case that there is the carrier frequency offset in the data of carrier which is inputted serially in the mixing unit 101b, when the data demodulation unit 101 performs the orthogonal transformation of the data at a high speed, the phase of data is shifted circularly as much as the integer part value of the carrier frequency offset.

The data of carrier which is transformed orthogonally through the fast Fourier transform unit 101c is converted serially through the parallel to serial conversion unit 101d and it is supplied to a movable terminal a of the first mode switch unit 102 such as an analog switch.

At this time, when the controller 108 attaches the movable terminal a to a fixed branch b by controlling the first mode switch unit 102 to perform the coarse mode, the data of carrier which is converted by the parallel to serial conversion unit 101d is supplied to the symbol accumulating unit 103 through the movable branch a and the fixed branch b of the first mode switch unit 102.

The symbol accumulating unit 103 calculates the strength of the integer part of the carrier frequency offset from the data of carrier which is currently inputted and accumulates the calculated value and the strength of the carrier frequency offset which is delayed by one symbol during several symbol periods, and thereby the accumulated value is supplied to the hold value detecting unit 104.

oscillating unit 109 through the second mode switch unit 107 by calculating the detected envelope value by the envelope detecting unit 104a.

Moreover, the offset detecting unit 105 includes: a continuous pilot extracting unit 105a for extracting a continuous pilot signal from the serial data of carrier which is obtained by the first mode switch unit 102; a third symbol delay unit 105b for delaying the extracted continuous pilot signal by one symbol period; and a subtracting unit 105c for obtaining the phase difference between the continuous pilot signal which is delayed during one symbol period and a present continuous pilot signal and then supplying to the first-order active loop filter unit 106.

Referring to Figure 1, the operation of the embodiment of the present invention will be illustrated in detail.

First, when the data of carrier is inputted through the input terminal 100, the data demodulation unit 101 samples the received signal by an oscillating feedback voltage which is obtained by the voltage-controlled oscillation unit 109, and then supplies the sampled data to the first mode switch unit 102.

In other words, the data of carrier which is inputted serially through the input terminal 100 is converted into the parallel data by the serial to parallel conversion unit 101a of the data demodulation unit 101, and it is mixed with the oscillating voltage which is inputted by the voltage-controlled oscillation unit 109 in the mixing unit 101b, and then it is supplied to the fast Fourier transform unit 101c.

switching and controlling the first and second switch units 102 and 107 with a predetermined time difference.

The data demodulation unit 101 includes: a serial to parallel conversion unit 101a for converting the inputted data of carrier by the input terminal 100 into parallel data; a mixing unit 101b for mixing the converted parallel data by the serial to parallel conversion unit 101a and the oscillated voltage which is fedback by the voltage-controlled oscillating unit 109; a fast Fourier transform unit 101c for extracting a sample data by converting the mixed data of carrier by the mixing unit 101b in orthogonality; and a parallel to serial conversion unit 101d for converting the sample data of carrier which is inputted by the fast Fourier transform unit 101c into serial data and outputting the data.

Moreover, the symbol accumulating unit 103 includes: an absolute value calculating unit 103a for calculating the signal strength of the data of carrier which is obtained by the first mode switch unit 102; first and second symbol delay units 103b and 103c for successively delaying the symbol as one symbol unit by considering the signal strength calculated by the absolute value calculating unit 103a; and first and second adding units 103d and 103e for accumulating the strength value of the delayed signal by the first and second symbol delay units 103b and 103c and the strength value of the signal which is obtained by the absolute value calculating unit 103a and then outputting the accumulated value.

The hold value detecting unit 104 includes: an envelope detecting unit 104a for detecting an envelope by comparing the accumulated value of the signal strength obtained by the second adding unit 103e with a predetermined threshold value th1; and a rise edge detecting unit 104b for controlling the voltage-controlled

(OFDM) transmission system according to the present invention.

Referring to Figure 1, the apparatus for a synchronizing carrier frequency of the OFDM transmission system includes: a data demodulation unit 101 for sampling a received signal by an oscillating feedback voltage from the obtained data of carrier by input terminal 100; a first mode switch unit 102 for switching the demodulated carrier by the data demodulator 101 into a coarse mode or a fine mode; a symbol accumulating unit 103 for accumulating the calculated strength value of the frequency offset from the obtained data of carrier which is inputted by the first mode switch unit 102 and the strength value of the accumulated carrier frequency offset which is delayed by one symbol duration; a hold value detecting unit 104 for detecting a hold value by calculating the strength value of the accumulated carrier frequency offset until the value arrives at a threshold value; an offset detecting unit 105 for detecting the frequency offset from the demodulated carrier obtained by the first mode switch unit 102 and then obtaining the phase difference between the carrier frequency offset of this symbol and that of the previous symbol; a first-order active loop filter unit 106 for controlling the gain of the obtained phase difference by the offset detecting unit 105; a second mode switch unit 107 for selecting and outputting one value out of the phase difference value which is filtered and then obtained by the first-order active loop filter unit 106 and the hold value obtained by the hold value detecting unit 104; and a voltage-controlled oscillating unit 109 which is locked to the hold value or phase difference value which is selected by the second mode switch unit 107 for correcting the integer part and the prime part of the carrier frequency offset of the data demodulation unit 101; and a control unit 108 for

signal by one symbol period; and a subtracting unit for obtaining the phase difference between the continuous pilot signal which is delayed during one symbol period and a present continuous pilot signal.

As a result, it is possible to exactly correct the integer part of carrier frequency offset in the coarse mode for compensating the integer part of the carrier frequency offset and in the fine mode for compensating the prime part, with a predetermined time difference. Accordingly, even in the case that the carrier frequency offset is above the bandwidth of one subchannel, the integer part and the prime part of the carrier frequency offset can be corrected, thereby resulting in the exact synchronization of carrier frequency.

A more complete appreciation of the present invention, and many of the attendant advantages thereof, will become readily apparent as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings in which like reference symbols indicate the same or similar components, wherein:

Figure 1 is a block diagram illustrating an embodiment of a synchronizing apparatus of carrier frequency in an OFDM transmission system according to the present invention.

The objects, characteristics and advantages of the above-described invention will be more clearly understood through the preferable embodiments referring to the attached drawings.

Figure 1 is a block diagram illustrating a preferred embodiment of apparatus for a synchronizing carrier frequency of an orthogonal frequency division multiplexing

parallel data; a mixing unit for mixing the converted parallel data by the serial to parallel conversion unit and the oscillated voltage which is feedback by the voltage-controlled oscillating unit; a fast Fourier transform unit for extracting a sample data by converting the mixed data of carrier in orthogonality; and a parallel to serial conversion unit for converting the sample data of carrier into serial data and outputting the data.

Preferably, the symbol accumulating unit includes: an absolute value calculating unit for calculating the signal strength of the data of carrier which is obtained by the first mode switch unit; at least one symbol delay unit for successively delaying the symbol as one symbol unit by considering the signal strength calculated by the absolute value calculating unit; and an adding unit for accumulating the strength value of the delayed signal by the symbol delay unit and the strength value of the signal obtained by the absolute value calculating unit and then outputting the accumulated value.

The hold value detecting unit preferably includes: an envelope detecting unit for detecting an envelope by comparing the accumulated value of the signal strength obtained by the adding unit with a predetermined threshold value; and a rise edge detecting unit for controlling the voltage-controlled oscillating unit through the second mode switch unit by calculating the detected envelope value.

Preferably, the offset detecting unit includes: a continuous pilot extracting unit for extracting a continuous pilot signal from the serial data of carrier which is obtained by the first mode switch unit; a symbol delay unit for delaying the extracted continuous pilot

Preferably, at least two said symbol delay means and adding means are provided and accumulates the signal strength of the carrier during at least two symbols.

Said threshold value may be obtained by averaging the signal strengths of the carrier and compared with the value which is accumulated during a predetermined symbol.

Said rise edge detection means preferably performs counting until the envelop value detected by said envelop detection means becomes larger than said threshold value and then supplies said counted value said voltage-controlled oscillating means.

Said loop filter means preferably comprise a first-order active loop filter having both a proportional gain for controlling the input signal of said voltage-controlled oscillating means directly by the present output of said offset detecting means and an integer gain for controlling input signal of the voltage-controlled oscillating means by averaging the previous outputs of said offset detecting means.

The apparatus preferably comprises a controller for controlling said first and second switch means according to the coarse mode and the fine mode.

Said controller may decide said fine mode according to the accumulated value of the symbol of said symbol accumulating means and controls said first and second mode switch means.

The data demodulation unit preferably includes: a serial to parallel conversion unit for converting the inputted data of carrier by the input terminal into

by said first mode switch means; symbol delay means for delaying the symbol successively as one symbol duration by considering said signal strength calculated by said absolute value calculating means; and adding means for accumulating said strength value of the delayed signal by said symbol delay means and said strength value of the obtained signal by said absolute value calculating means and then outputting the accumulated value.

Said hold value detection means preferably comprises: envelope detecting means for detecting an envelope by comparing said accumulated value of the signal strength obtained by said adding means with a predetermined threshold value; and rise edge detection means for controlling said voltage-controlled oscillating means through said second mode switch means by calculating the detected envelope value by said envelope detecting means.

Said offset detection means may comprise: continuous pilot extracting means for extracting a continuous pilot signal from the serial data of carrier which is obtained by said first mode switch means; symbol delay means for delaying and outputting said extracted continuous pilot signal by one symbol period; and subtracting means for obtaining the phase difference between said continuous pilot signal which is delayed during one symbol period and a present continuous pilot signal and then supplying to said loop filter means.

Said absolute value calculating means may obtain the signal strength of said carrier by squaring an absolute value.

value; an offset detecting unit for detecting the frequency offset from the demodulated carrier obtained by the first mode switch unit and then obtaining the phase difference between the carrier frequency offset and the carrier frequency offset of the previous symbol; a loop filter unit for controlling the gain of the obtained phase difference; a second mode switch unit for selecting and outputting one value out of the phase difference value which is filtered and then obtained and the hold value obtained by the hold value detecting unit; and a voltage-controlled oscillating unit which is locked to the hold value or phase difference value which is selected by the second mode switch unit for correcting the integer part and the prime part of the carrier frequency offset of the data demodulation unit.

The apparatus preferably includes control means for switching and controlling the first and second switch means with a predetermined time difference.

Said data demodulation means preferably comprises: serial to parallel conversion means for converting said inputted data of carrier into parallel data; mixing means for mixing said converted parallel data and said oscillated voltage which is feedback by said voltage-controlled oscillating means; fast Fourier transform means for extracting sample data by converting said mixed data of carrier in orthogonality by said mixing means; and parallel to serial conversion means for converting said sample data of carrier into serial data and outputting said data.

Said symbol accumulating means preferably comprises: absolute value calculating means for calculating the signal strength of said data of carrier which is obtained

phase differences of pilots within one symbol by a predetermined value.

The phase difference between the adjacent symbols is preferably obtained by dividing said average value of the phase differences of pilots within one symbol by $2\pi\_(1+\Delta)$.

The prime part of said carrier frequency offset may be corrected within a predetermined Hz by controlling the gain proportionally with the calculated value of the phase difference.

Preferably, the threshold value is set to the half the strength value of the received carrier.

Preferably, the phase difference is obtained by dividing the averaged value of the phase differences between each pilot and its previous pilot within one symbol duration by a predetermined value.

According to another aspect of the present invention, an apparatus for synchronizing the carrier frequency of the OFDM transmission system includes: a data demodulation unit for sampling a received signal by an oscillating feedback voltage from the obtained data of carrier; a first mode switch unit for switching the demodulated carrier into a coarse mode and a fine mode; a symbol accumulating unit for accumulating the calculated strength value of the frequency offset from the obtained data of carrier and the strength value of the accumulated carrier frequency offset which is delayed by one symbol duration; a hold value detecting unit for detecting a hold value by calculating the strength value of the accumulated carrier frequency offset until the value arrives at a threshold

receiving the carrier which is transmitted from a transmitter in the case of selecting the fine mode; calculating a phase difference between the extracted pilot signal and a previous extracted pilot signal which is delayed by one symbol duration; and correcting the prime part of the received carrier frequency offset within a predetermined frequency by controlling a gain of the calculated phase difference.

Preferably, the signal strength of said carrier frequency is obtained by the square of an absolute value of the signal amplitude.

The correction of the integer part of said carrier frequency offset may be performed within a predetermined frequency bandwidth between each carrier.

After averaging said calculated signal strength of the carrier, the averaged value is preferably set as an established value which is the comparative value of the signal strength of the carrier.

The correction of the integer part of said carrier frequency offset is preferably performed by accumulating the calculated signal strength of the present carrier and the signal strength of a previous carrier during at least two symbol periods.

The integer part of said carrier frequency offset is preferably corrected within a half frequency bandwidth of one subchannel.

Said phase difference is preferably obtained by dividing the value which is obtained by averaging the

however, above the bandwidth of one subchannel, it is difficult to measure the rotational amount of the phase, and thereby the synchronization is also failed.

Therefore, it is an aim of preferred embodiments of the present invention to provide a method and apparatus for synchronizing a carrier frequency of orthogonal frequency division multiplexing (OFDM) transmission apparatus capable of successfully synchronizing the carrier frequency even in the case that the offset of the carrier frequency is above the bandwidth of one subchannel.

It is another aim to synchronize the carrier frequency by cooperating both a coarse mode for compensating an integer part of a carrier frequency offset and a fine mode for compensating a prime part of the carrier frequency offset, in turn with a predetermined time interval.

According to one aspect of the present invention, a method for synchronizing a carrier frequency of the OFDM transmission system includes the steps of: determining which mode out of a coarse mode for correcting an integer part of a carrier frequency offset and a fine mode for correcting a prime part is selected; calculating the strength of carrier which is received in each subchannel in the case of selecting the coarse mode; accumulating the calculated strength of the carrier and the strength of a previous carrier which is delayed by one symbol duration for a predetermined period; calculating the accumulated value of the strength of the carrier until the value arrives at a predetermined threshold value and correcting the integer part of the received carrier frequency offset using the calculated value; extracting a pilot signal by

is divided into an integer part and a prime part through a normalization by the frequency bandwidth of one subchannel.

The integer part of the offset causes the signals by the fast Fourier transform (FFT) to be circularly shifted at a receiver, and its prime part causes the power and phase of the signals to be disturbed by an interference with the subchannels.

As described above, when the carrier frequency is offset between a transmitter and a receiver, as a result, the offset of the carrier frequency causes the interference between the carriers of subchannels, and the orthogonality between the subchannels cannot be maintained, thereby increasing the error rate of transmitted data.

In the OFDM transmission systems, for methods which can be used in a terrestrial high definition television, a 8K discrete Fourier transform (DFT) and a 2K discrete Fourier transform are standardized. The recovery of the carrier has been developed as the main technology of the transmission.

The existing methods for synchronization used in the OFDM transmission system, synchronize the carrier frequency by using the fact that its phase is rotated uniformly in the case that the carrier frequency is not synchronized.

The conventional methods for synchronization in the OFDM transmission apparatus works well when the carrier frequency offset is within the bandwidth of one subchannel. When the carrier frequency offset is,

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METHOD AND APPARATUS FOR SYNCHRONIZING A CARRIER FREQUENCY OF AN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING TRANSMISSION SYSTEM

The present invention relates to a synchronization of carrier frequency in an orthogonal frequency division multiplexing (OFDM) transmission apparatus, and particularly to a method and apparatus for synchronizing a carrier frequency of an orthogonal frequency division multiplexing (OFDM) transmission apparatus capable of synchronizing a carrier frequency efficiently even if a carrier frequency offset is above the frequency bandwidth of one subchannel by cooperating both a coarse mode for synchronizing an integer part of the carrier frequency offset and a fine mode for synchronizing a prime part of the carrier frequency offset when performing the synchronization of carrier frequency in the OFDM transmission apparatus.

Generally, a digital television adopts a frequency division multiplexing (FDM) transmission system which is one of the multiple carrier modulation methods. It occupies an almost equal frequency bandwidth required in transmitting data a single carrier, since the data have the longer symbol period by being transmitted in parallel on several subchannels. The FDM signal is generated by an inverse fast Fourier transform (IFFT) and its modulation in parallel by carriers which are orthogonal to each other.

At this time, a synchronization of carrier frequency should be achieved between a transmitter and a receiver before performing a fast Fourier transform at the receiver. When the carrier frequency is offset between a transmitter and a receiver, the carrier frequency offset